Nano-manufacturing

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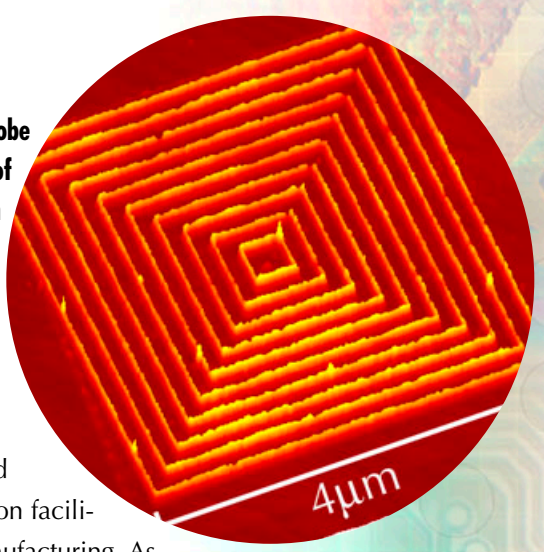
Program Funding:	$5.0 M
FTEs:	25

Program Goal

Develop and deliver timely measurements, standards, and infrastructural technologies that address identified critical U.S. industry and other government agency needs for innovation and traceable metrology, process-control and quality in manufacturing at the nanoscale.

Problem

Advanced nanomanufacturing is key to the strength and future growth of the U.S. manufacturing sector and a strong measurements and standards infrastructure is vital for its success. It has been predicted that within the next 10 years, at least half of the newly designed advanced materials and manufacturing processes will be built at the nanoscale. Measurement science (metrology) and advanced instrumentation are essential for nanomanufacturing. Metrology is a key enabler for all manufacturing. If you cannot measure it, you cannot make it and that statement is even more accurate in the regime of nanotechnology. Successful metrology infrastructure is essential for manufacturers to achieve the real promise of developing and manufacturing new nanomaterials, devices, and products. Advanced instrumentation provides the necessary data upon which sound scientific conclusions can be based and correct metrology provides the ability to interpret those data properly and accurately. Together, a successful metrology infrastructure and advanced instrumentation facilitate nanomanufacturing. As pointed out in the National Nanotechnology Initiative (NNI) Instrumentation Grand Challenge workshop final report, some of these metrology techniques will be evolutionary and some will be revolutionary. With that in mind, it is imperative that this program remain agile and evolve with the nanomanufacturing industry and adapt as new applications develop.



Scanned probe oxidation of hydrogen terminated silicon

Approach

The main theme of this research is "Developing the Nanometrology Infrastructure for Nanomanufacturing." The three fundamental thrust areas are: 1) Imaging and Metrology, 2) Nano-Fabrication, and 3) Control and Assembly Each of these areas addresses unique aspects regarding nanometrology infrastructure. The unique integration of these thrust areas into this program facilitate knowledge exchange to maximize the outcomes of the program.

Typical Customers and Collaborators

- University of Maryland
- Advanced Micro Devices
- Soluris
- International SEMATECH
- Hitachi High Technologies
- FEI Company
- E. Fjeld Company
- NASA
- Spectel Research
- INTEL
- IKLA Tencor
- Semiconductor Research Corp.
- Photronics and Dupont Photomask
- Nova Metrology tools
- Zyvex Corporation

For more information see page 98

Nanomanufacturing

Program Goal

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Program Manager:
Michael T. Postek

Total FTEs:
25

Annual Program Funds:
$5.029 M

Customer Need & Intended Impact

Advanced nanomanufacturing is key to the strength and future growth of the U.S. manufacturing sector and a strong measurements and standards infrastructure is vital for its success. NIST is responsible to U. S. manufacturing for providing traceability to the national unit of length, by developing measurement capabilities and calibration standards. Metrology is a key enabler for all manufacturing and it is especially important to nanotechnology. It has been predicted that within the next 10 years, at least half of the newly designed advanced materials and manufacturing processes will be built at the nanoscale. Measurement science (metrology) and advanced instrumentation are essential for nanomanufacturing. If you cannot measure it you cannot make it and that statement is even more accurate in the regime of nanotechnology. Successful metrology infrastructure is essential for manufacturers to achieve the real promise of developing and manufacturing new nanomaterials, devices, and products. Advanced instrumentation provides the necessary data upon which sound scientific conclusions can be based and correct metrology provides the ability to properly and accurately interpret those data. Together they facilitate nanomanufacturing. As pointed out in the National Nanotechnology Initiative (NNI) Instrumentation and Metrology Grand Challenge workshop final report, some of these metrology techniques will be evolutionary and some will be revolutionary. With that in mind, it is imperative that this program remain agile and evolve with the nanomanufacturing industry and adapt as new applications develop. It has been proven that where the economy of scale in manufacturing is concerned, even relatively small improvements in the metrology in the manufacturing process can yield large savings and increased value to the U. S. Economy.

Technical Approach & Program Objectives

This program represents an integrated approach to the currently known nanomanufacturing needs with an eye on the anticipated needs which will soon emerge. Therefore agility will be the key to the success of the technical approach. By integrating instrument development, and metrology infrastructure development a strong package of MEL metrology capability can be presented to the customer base.

Objective #1: SEM for Nanoscale Measurements

Develop the best-in-the-world accurate 3-dimensional Scanning Electron Microscope (SEM)-based dimensional metrology and modeling capable of measurement resolution of less than 0.1 nm and apply these to real-world samples to meet the requirements of the current and emerging nanomanufacturing in microelectronics, nanotechnology and biotechnology.

Deliverables for FY2005:

The new high-resolution, environmental, laser interferometer stage metrology SEM installed in the Advanced Measurement Laboratory (AML).

Deliverables for FY2006:

Extension of modeling capabilities of NIST's Monte Carlo (MONSEL) electron trajectory simulator to include two- and three-dimensional samples of arbitrary shape.

Deliverables for FY2007:

New, accurate 3-dimensional metrology coupled with modeling that allows the comprehensive experimentation on both virtual and real samples with nanometer uncertainty.

Deliverables for FY2008:

Validated MONSEL for low electron landing energy images and its capabilities extended to simulate low-vacuum (environmental) imaging modes (used for charge compensation when imaging insulating samples such as photomasks or biological samples) and the results published

Deliverables for FY2009:

A new state-of-the-art reference dimensional metrology SEM and accurate metrology methods for full-size wafers and masks. This work will carried out in cooperation with participants from the U.S. nanomanufacturing industry.

Objective #2: Optical Metrology

Provide world class metrology capabilities and technical leadership using optical based methods capable of measuring photomasks, reflection mode targets (as on wafers or industrially relevant substrates), and feature to feature positions with unsurpassed accuracy on features used in the most advanced nanoelectronics manufacturing.

Deliverables for FY2005:

Models and metrology targets; new overlay metrology methods that support the manufacturing of nanolelectronic devices at the 65 nm node and that can extend optical technology to the 65 nm sized manufacturing domain.

Deliverables for FY2006:

New scattering models for line width evaluation in transmission mode; advanced models necessary for optical metrology at the 32 nm node including reflection and transmission modeling of phase shifting features developed and tested in conjunction with industry.

Deliverables for FY2007:

A comprehensive set of Overlay Wafer Standard Reference Materials (SRMs), calibrated photomask linewidth features and 2-dimensional grids artifacts.

Deliverables for FY2008:

Advanced optical measurement methods capable of sub-1 nm repeatability and nanometer accuracy for use in nanoelectronics and nanomanufacturing feature metrology and process control.

Deliverables for FY2009:

A new optical metrology methodology useful in integrated metrology applications based on scatterfield microscopy.

Objective #3: Atom Based Metrology

Develop the best in the world atomic-scale metrology for measurements and standards in support of nanomanufacturing and nanoelectronics. Enable the capability to measure feature dimensions and positions with atomic precision and to fabricate test structures with sub-5 nm dimensions to support and enable developing advanced atomic-scale measurement capabilities.

Deliverables for FY2005:

Procurement of a new Scanning Tunneling Microscope (STM) that has improved atomic scale imaging capability for atom-based dimensional metrology.

Deliverables for FY2006:

Improved methods for etching nanostructures written in silicon work (in collaboration with ISMT (International Sematech) and the NIST Electronics and Electrical Engineering Laboratory (EEEL).

Deliverables for FY2007:

Techniques for the preparation of Scanning Probe Microscope (SPM) tips with reproducible geometries and the direct characterization of the SPM tip geometry and dimensions on the atomic scale.

Deliverables for FY2008:

Evaluation and demonstration of the use of nanotube tips for use in atomic scale metrology and nanolithography. Perform field emission testing to evaluate electrical characteristics.

Deliverables for FY2009:

Features written in silicon with critical dimensions smaller than 3 nm; The process developed so it can be implemented in other nanolithography systems and measured in external metrology systems.

Objective #4: SPM for Nanoscale Measurements

Develop world class traceable calibrations of probe-based calibration systems and procedures for the measurement of dimensional parameters for the semiconductor and other microelectronics industries with nanometer- and subnanometer-level uncertainties.

Deliverables for FY2005:

A SPIE (International Society for Optical Engineering) presentation and article on the development of the Veeco SXM (Scanning Probe Microscope) measurement system for linewidth measurement.

Deliverables for FY2006:

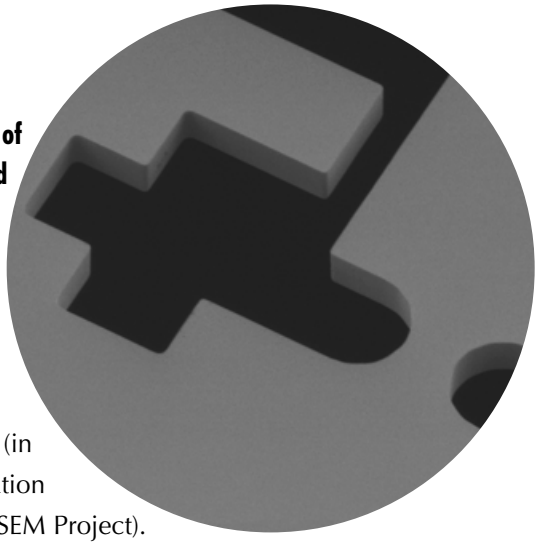
Calibrated pitch, height, and linewidth artifacts for maintaining and demonstrating the traceability of the instrument and SPIE presentation and article on the system concept and measurement results.

Deliverables for FY2007:

An independently traceable linewidth measurement technique, based on image stitching and the use of nanotube probes, for independent verification of the critical dimension (CD)-Atomic Force Microscope (CD-AFM) and an optimized reference measurement system at ISMT closely coupled both to NIST and to industry, providing traceable measurements of pitch, step-height, linewidth, and Line-Edge Roughness (LER).

Deliverables for FY2008:

A journal article on the comparison of the results of three independently traceable linewidth measurement techniques: the CD-AFM, image stitching, and SEM (in collaboration with the SEM Project).



Combination of circular and cantilever cut flexures

Deliverables for FY2009:

Traceable, CD-AFM-based linewidth measurement service for linewidth as small as 50 nm with uncertainties consistent with the sub nanometer resolution levels now required in industrial measurements (see: the International Technology Roadmap for Semiconductors ITRS) and capable of pitch and step height measurements as well.

Objective #5: Force Metrology for Nanoscale Measurements and Standards

Develop world-class force metrology for nanoscale measurements and standards for nanomanufacturing capable of improving the realization of the unit of force below 10^{-5} N by measuring a nanonewton with an expanded relative uncertainty below a percent.

Deliverables for FY2005:

A paper and review article on microforce submitted to the SPIE Microlithography Conference to introduce this topic to that community with potential resubmission to the Journal of Microlithography, Microfabrication and Microsystems.

Deliverables for FY2006:

A force and displacement measuring instrument capable of moving a rigid probe element or load cell into contact with the moving pan of the Electrostatic Force Balance (EFB) while recording force with 10 pN resolution and observing the relative separation of the probe and balance pan with 10 pm resolution.

Deliverables for FY2008:

A secondary force standard based on piezoresistive load sensing.

Deliverables for FY2009:

Examination of intrinsic force standards.

Objective #6: Advanced Control Systems and Positioning

Develop world-class advanced control and positioning systems for nanoscale measurements, assembly and standards. This includes arrays of high-precision Micro Electro-Mechanical Systems (MEMS) stages for scanning probe microscopy; multi-degree-of-freedom nanometer resolution fiber optic displacement sensors; and the automated assembly of micro and nano-scale components.

Deliverables for FY2006:

Fabrication of a 2 x 2 array of MEMS-based x-y-z positioning stages. The displacement range, frequency bandwidth and parasitic errors determined using an SEM. Additional tests will be performed at the EEEL MEMS testing laboratory to determine the thermal properties and out-of-plane stage motion. The results presented at an appropriate scientific conference and submit a paper to an appropriate scientific journal.

Deliverables for FY2006:

Integration of existing high-precision micromanipulation robot with an intelligent control architecture. This system will be used to prototype various microassembly operations that are critical to industry needs. Demonstration of a 4 degrees-of-freedom (DOF) peg-in-hole microassembly operation using NIST-developed microcomponent artifacts.

The results presented at an appropriate scientific conference and submit a paper to an appropriate scientific journal.

Deliverables for FY2007:

Test arrays of high-precision MEMS stages for scanning probe microscopy that will have better accuracy and resolution than commercial instruments and that will provide increased scanning area per unit of time due to parallel operation; The results presented at an appropriate scientific conference and submit a paper to an appropriate scientific journal.

Deliverables for FY2007:

A calibrated six degree-of-freedom fiber optic displacement sensor. It will be incorporated into a scanning probe microscope to measure the displacement and rotation of the scanning probe. The results presented at an appropriate scientific conference and submit a paper to an appropriate scientific journal.

Objective #7: Optical Tweezers for Nanoscale Manipulation and Metrology

Develop a best in the world capability to manipulate, assemble and test nano-scale devices such as nanowires using optical forces that combine laser-based manipulation, operator interface and automation to open new avenues for creating and testing nanodevices.

Deliverables for FY2005:

Functional nanodevices developed using semiconductor nanowires and publication of the results in a leading journal such as Applied Physics Letters.

Deliverables for FY2006:

A particle count standard fabricated by assembling a fixed number of particles into a suitable sample for calibration of particle counting instruments (in liquid) and disseminate to appropriate alpha test sites.

Deliverables for FY2009:

A new Nano-tweezers instrument based on innovative trapping physics and imaging techniques to manipulate and visualize much smaller components than is currently possible anywhere in the world using grid computing to allow 3D visualization in real time with resolution better than 30 nm.

Objective #8: Advanced Lithography

Develop a world class capability to fabricate test samples and standards using scanning probe oxidation and utilizing the unique capabilities afforded by the high accuracy scanning probe placement of the Molecular Measuring Machine; and develop a competence in imprint lithography which will enable nanomanufacturing of standards.

Deliverables for FY2005:

Reliable, effective methods and parameters for pattern transfer (i.e., etching) that utilize the SPM oxidation features as a mask.

Deliverables for FY2006:

A predictive model for SPM oxidation kinetics for optimized line width control of latent oxide features. The model will include the influence of electronic and ionic transport on the intrinsic thickness growth and lateral spreading due to space charge.

Deliverables for FY2007:

Prototypes of 1-D and 2-D silicon calibration structures.

Deliverables for FY2008:

Replication of sub-50-nm features using nanoimprint lithography, and verification of the fidelity and scale accuracy of the transferred patterns over macroscopic distances

Deliverables for FY2009:

A photomask for a standardized template for directed cell growth.

Objective #9: Nanomachining Technologies

Develop enabling technologies for Nanomanufacturing utilizing machine technologies to build interfaces that link nano devices to the physical world as well a fabricate imprint lithographic masks.

Deliverables for FY2005:

Participation in World Technology Evaluation Center (WTEC) survey of state of the art in micro machining.

Deliverables for FY2006:

Journal paper detailing design and characterization of metrology frame for improving accuracy of desktop machine used for micro machining.

Deliverables for FY2007:

Journal paper detailing micro/nano imprint manufacturing methods developed.

Deliverables for FY2009:

Demonstration of the combination of machining methodology with lithographic capabilities for nanoimprint masks.

Major Accomplishments

NNI Workshop on Instrumentation and Metrology for Nanotechnology

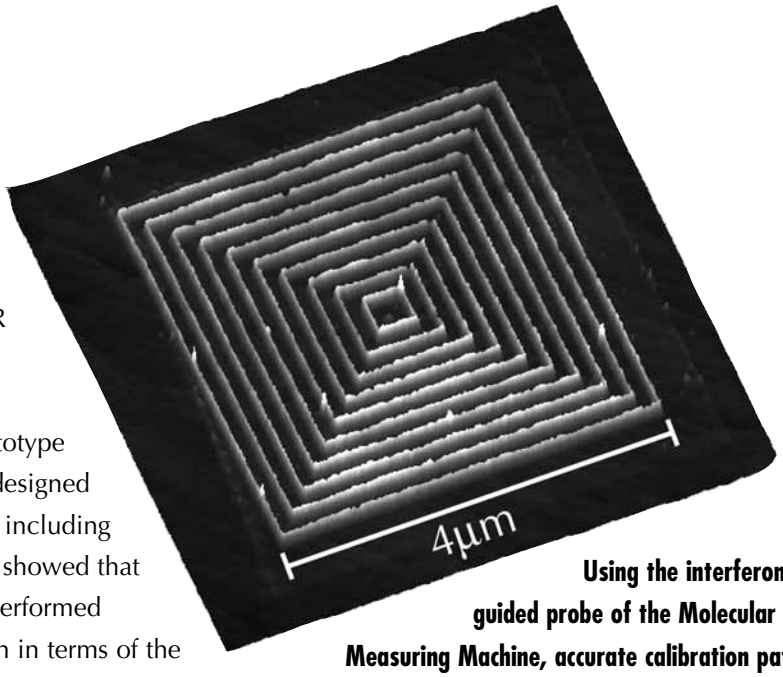
NIST held a very successful workshop on Instrumentation and Metrology for Nanotechnology in support of the National Nanotechnology Initiative. More than 250 attendees participated in the plenary sessions as well as the five breakout tracks. The overall conference was organized and chaired by Michael Postek and the Nanofabrication Breakout session was co-chaired by Richard Silver. There were numerous presentations in the sessions by international leaders within the various nanotechnology specialties. The output goal is a document that summarizes key goals, obstacles, roadblocks, and strategies aimed at achieving the visionary goals. This document will be used by the President's Council of Advisors on Science and Technology (PCAST) and other government funding agencies to provide direction and need for key research objectives and collaborations.

Successful Completion Of SEMATECH Assignment

Ronald Dixson, a program member, completed a two year assignment at International SEMATECH. The primary focus of the assignment was the development of a reference measurement system (RMS) using a critical dimension atomic force microscope (CD-AFM). The Veeco Dimension X3D – which is the current commercially available CD-AFM – was implemented as an RMS. Uncertainty budgets were developed and the instrument performance was thoroughly characterized.

Comparison of AFM-based Line Edge Roughness (LER) Measurements

A comparison of AFM-based LER measurements were performed using the SEMATECH Advanced Metrology Advisory Group's prototype standards with an intentionally designed LER. Different probes were used including carbon nanotube tips. The study showed that the carbon nanotube AFM tips performed better than other techniques both in terms of the ability to image closely spaced features and in being able to reach deep valleys.



Using the interferometer-guided probe of the Molecular Measuring Machine, accurate calibration patterns can be produced. For this artifact, the writing method was scanned probe oxidation of hydrogen terminated silicon.

Scanning Electron Microscope Modeling Proposal and Line Edge Roughness Recommendations

The meetings of the International SEMATECH (ISMT) Metrology Council draw a mix of metrologists representing ISMT member companies (semiconductor manufacturers), manufacturers of metrology tools, and government, business, and academic researchers. John Villarrubia, a program member, made a proposal for development of scanning electron microscope (SEM) models to support measurement of a greater range of sample shapes and compositions with more general detector placement. John also described two possible solutions to a measurement bias problem in line edge roughness measurement and recommended changes in the industry roadmap, since current specifications actually favor the incorrect measurement.

New Photomask Standard, Calibrated in a Unique Industry/NIST Collaboration

The new SRM 5001, the two-dimensional grid standards, were delivered to the NIST SRM office. This represents the first time this new standard 6 inch (15.24 cm) photomask has been delivered to the SRM office. This SRM is expected to provide a traceable standard for the calibration of photomask positioning metrology tools as well as tools that require accurate placement of a wafer within the field of view.

NIST Paper Receives SPIE Metrology Best Paper of 2003 Award

The paper, "Simulation Study of Repeatability and Bias in the CD-SEM," by John Villarrubia, András Vladár, and Michael Postek was selected by vote of conference officials as the best of the approximately 129 papers presented at the 2003 SPIE Conference on Metrology, Inspection, and Process Control.

Invention Disclosures Submitted On Two Revolutionary Advances In Optical Metrology

Researchers from the overlay metrology project submitted two Invention Disclosure and Rights Questionnaire forms (CD 240) for the disclosure of recent potential breakthrough material in high resolution optical metrology. As a part of this disclosure, a new target design that occupies only a few square microns of space was unveiled. The second CD 240 focused on a new proposed method for critical dimension metrology using through-focus focusmetric signatures that have shown near to nanometer-scale sensitivity to changes in linewidth.

Overlay Metrology Methods To Be Adopted By Industry

The overlay metrology project has made available recent important research results on optical characterization, Charge-Coupled Device (CCD) data acquisition calibration, and focus and edge detection work. In-depth discussion were held this year between the NIST overlay project leader and technical representatives from all four of the leading overlay tool manufacturers including Hitachi, Nikon, KLA-Tencor and Sclumberger.

MEMS-scale One Degree Of Freedom High Precision Micro/Nano Positioners Fabricated

NIST designed and fabricated micro-scale versions (i.e., MEMS) of the NIST/MEL one degree of freedom high precision micro/nano positioner, with several feature and dimensional variations. Fifteen silicon dies of this and other calibration devices were fabricated with the collaboration of researchers from the Rensselaer Polytechnic Institute Center for Automation Technologies (RPI/CAT). Each die has a dimension of 10 mm by 10 mm and contains 24 separate devices. The dies were divided among the NIST and RPI/CAT research groups and are currently undergoing performance testing, modeling and calibration.

CRADA with RPI/CAT

A three year cooperative research and development (R&D) agreement between the Center for Automation Technologies, Rensselaer Polytechnic Institute and NIST was signed. The two organizations will be working on a project titled: Modeling and Performance Study of MEMS Positioning Devices.

Field Ion Microscope Images Of Nanotubes Obtained In Collaboration With George Washington University

In a collaboration established in early 2004 between the George Washington University and researchers in the NIST Atom-based Dimensional Metrology project, significant progress has been made in characterizing the ends of the nanotubes by directly imaging the nanotube emitters.

Application of Model-Based Library Metrology to Resist Lines

A study of the model-based library (MBL) technique for SEM critical dimension metrology applied to resist samples has been completed. The NIST-developed technique was applied to polycrystaline silicon samples in previous years. This study of its application to resist samples was motivated by the importance of resist measurements to process control in semiconductor electronics manufacturing.

Additional Accomplishments

- Guest Researcher Hui Zhou completes his Final Defense of his Doctoral research
- "Integrated Metrology: Effective Hardware and Control Strategies" panel chaired by NIST
- "High-resolution Optical Overlay Metrology" presented SPIE Microlithography symposium in Santa Clara
- New Silicon step flow model developed at NIST
- Brad Damazo presentation on the new diode laser interferometry system
- Invited presentation at the ASME International Conference - "Nanotechnology: Measurements and Standards for Manufacturing"
- Invited paper at the Nanotech 2004 Conference
- Reflection mode optical measurements of phase shifting photomasks completed
- New Type MIT Micro Positioner tested
- NNI Research Directions II Workshop participation and invited presentation summarize the Grand Challenge Workshop on Instrumentation and Metrology by Michael Postek
- Invited Presentation "Nanometrology a Fundamental Need for Nanotechnology" at the Microscopy, Metrology and Manipulations using Electrons, Ions, and Photons for Nanophase Materials Workshop
- NIST participation at the NNI Strategic Planning Workshop
- Nova Measuring Instruments sends high level corporate staff for optics discussions
- NIST and SEMATECH collaborate to develop wafers to test new high resolution optical CD techniques
- Nick Dagalakis has been asked to serve as a liaison between the Robotic Industries Association (RIA) office of standards development and the, newly established ANSI/NSP
- Nick Dagalakis of ISD and John Kramar of PED have prepared a CRADA application with APNanotech, Inc.
- Transmission and Reflection Electromagnetic Scattering Theory Model Developed
- Picometer Interferometer Design Described to ASPE
- NIST Assists ISMT in Benchmarking Scatterometry Equipment
- Nanotech in Microlithography Technical Group Meeting held at SPIE 2004
- Successful SEM/XRM Course at NWAFS Spring Meeting
- Workshop on Electron Beam/Specimen Interaction Modeling at SCANNING Meeting
- Invited talk at NSF Workshop. B. Damazo gave an invited talk at the NSF workshop on micro-manufacturing
- Demonstrated a novel method for performing nano-imprint lithography on refractory metal substrates
- Developed a model for describing scanning probe oxidation kinetics of arbitrary materials systems using fractional reaction-diffusion equations
- Demonstration of the principal of Image Stitching Linewidth measurement and publication of two papers on the subject
- AFM measurements of Single Crystal Critical Dimension Reference materials (SCCDRM) specimens for EEEL and SEMATECH members
- Comparison of AFM-based line edge roughness measurements using SEMATECH prototype standards

FY2005 Projects

(Project descriptions can be found within the associated objective)

- Scanning Electron Microscope (SEM) for Nanoscale Measurements (Objective #1)
- Optical Metrology (OM) for Nanoscale Measurements (Objective #2)
- Atom Based Metrology for Nanoscale Measurements and Standards (Objective #3)
- Scanning Probe Microscopy for Nanoscale Measurements (Objective #4)
- Force Metrology for Nanoscale Measurements and Standards (Objective #5)
- Advanced Control Systems and Positioning for Nanoscale Measurements and Standards (Objective #6)
- Optical Tweezers for Nanoscale Manipulation and Metrology (Objective #7)
- Advanced Lithography for Nanoscale Measurements and Standards (Objective #8)
- Development of Nanomachining Technologies for Nanomanufacturing (Objective #9)

Typical Customers and Collaborators

- University of Maryland
- Advanced Micro Devices
- Soluris
- International SEMATECH
- Hitachi High Technologies
- FEI Company
- E. Fjeld Company
- Spectel Research
- INTEL
- KLA Tencor
- Semiconductor Research Corp.
- Photronics and Dupont Photomask
- Nova Metrology tools
- George Washington University
- NASA
- Johns Hopkins University – Applied Physics Laboratory
- Center for Automation Technologies, Rensselaer Polytechnic Institute
- Zyvex Corporation
- Newport Corporation
- Luna Technologies, Luna Innovations
- Duke Scientific
- University of Akron
- Georgetown University Medical Center

FY2005 Standards Participation

SEM Metrology

SEM magnification and linewidth standards are being fabricated; ASTM E42.14, ITRS metrology Technical Working Group (TWG).

Optical Metrology

Extensive participation in efforts at ISMT in the development of benchmarking efforts and standard measurement practices; representation on the Semiconductor Equipment and Materials International (SEMI) standards committees including co-chair for the Microlithography committee; development of photomask 2-dimensional grid standards as well as photomask standards and measurement practices within SEMI.

Atomic scale

Broad participation in efforts at ISMT in the develop of test structures and in the advanced semiconductor needs for linewidth metrology; representation on the SEMI standards committees including co-chair for the Microlithography committee.

SPM

Committee participant - ASTM E42.14 on STM/AFM; ASME B46 on the Classification and Designation of Surface Qualities.

Force

Demonstrated capability of providing SI (International System of units) traceable force as called for by ISO 14577-1,2, and 3 (Metallic materials — Instrumented indentation test for hardness and materials parameters).

Control

Participation in the Optoelectronics Assembly Subcommittee of the IPC, several standards for the handling, attachment, alignment and testing of optoelectronics are currently being drafted.

FY 2005 Measurement Services

Calibrations

- Linescale Interferometer calibration of length scales

Special Tests

- 2D grids and Overlay Measurements (internal)

SRMs

- SRM 2800 – New Optical Microscope micrometer
- SRM 2059 – New Photomask Linewidth (in process)
- SRM 2120/RM 8120 – SEM Linewidth (in process)
- SRM 2090/RM 2090 – SEM magnification
- SRM 2091/RM 8091 – SEM Sharpness
- SRM 5000 – Optical Overlay
- SRM 5001 – 2D Grids

Nanomanufacturing